Report Documentation Page

Form Approved OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
12 JUN 2014	**Summary**	**12 DEC 2013 - 12 MAY 2014**

4. TITLE AND SUBTITLE
Environmental Control Unit with Integral Thermal Storage

5a. CONTRACT NUMBER
W911QX-14-C-0014

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Michael C. Ellis Ryan McDevitt

5d. PROJECT NUMBER
0010437481

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Advanced Cooling Technologies, Inc. 1046 New Holland Avenue Lancaster, PA 17601

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army ACC APG / Adelphi Cont Div ACC APG / Adelphi Div 2800 Powder Mill Rd CCAP-SCA Adelphi, MD 20783-1197

10. SPONSOR/MONITOR'S ACRONYM(S)
RDRL-SED-E

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT
As part of an Office of the Secretary of Defense (OSD) Small Business Innovative Research (SBIR) Phase I project, Advanced Cooling Technologies, Inc. (ACT) evaluated an Environmental Control Unit (ECU) that uses an integrated PCM Heat Exchanger (PHX) to provide thermal energy storage. By storing thermal energy during the hottest part of the day and rejecting this stored energy during the coolest part of the day, the PHX can reduce the power consumption of an ECU by up to 10% over a 24 hour period. The PHX was demonstrated at ACTs laboratory using a low fidelity prototype.

15. SUBJECT TERMS
Environmental Control Unit, Thermal Storage, Phase Change Material, Load Leveling

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**2**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

As part of an Office of the Secretary of Defense (OSD) Small Business Innovative Research (SBIR) Phase I project, Advanced Cooling Technologies, Inc. (ACT) evaluated an Environmental Control Unit (ECU) that uses an integrated PCM Heat Exchanger (PHX) to provide thermal energy storage. To aid in the development of the PHX, as well as in the transition from research to product development, ACT partnered with a military ECU supplier and a commercial HVAC supplier. Each partner provided support on the design and modeling of the PHX/ECU system.

By storing thermal energy during the hottest part of the day and rejecting this stored energy during the coolest part of the day, the PHX can reduce the power consumption of an ECU by up to 10% over a 24 hour period. This reduction in energy consumption results from the increase in ECU efficiency that occurs when ambient conditions are more favorable for heat rejection. The coefficient of performance, which is the ratio of cooling achieved to power consumed, can vary by 50% or more during a typical diurnal cycle in a hot environment. The concept developed under Phase I of this program capitalizes on this variation with the goal of a 5 to 10% improvement in energy consumption for a military ECU.

Reducing the energy consumed by ECU's can have significant impact on military installations. For example, ECU's have been known to consume as much as 75-80% of the electrical power generated at Forward Operating Bases (FOB). A 2009 study showed that the 9 to 60 kBTUh ECU's used by the Army in the same year consumed 35.2 million gallons of fuel. The monetary cost of delivering this fuel was $14.33 per gallon for a total of $505 million. In addition, delivering fuel to remote locations is dangerous. In Afghanistan, fuel must be driven an average of 800 miles over 18 days to reach Army bases. In 2011, over 1,000 deaths were associated with these fuel convoys. By reducing ECU power consumption by 10%, fuel consumption can be reduced by 3.9 million gallons of fuel, which is the monetary equivalent of $56 million. More importantly, reducing the number of fuel convoys can save lives.

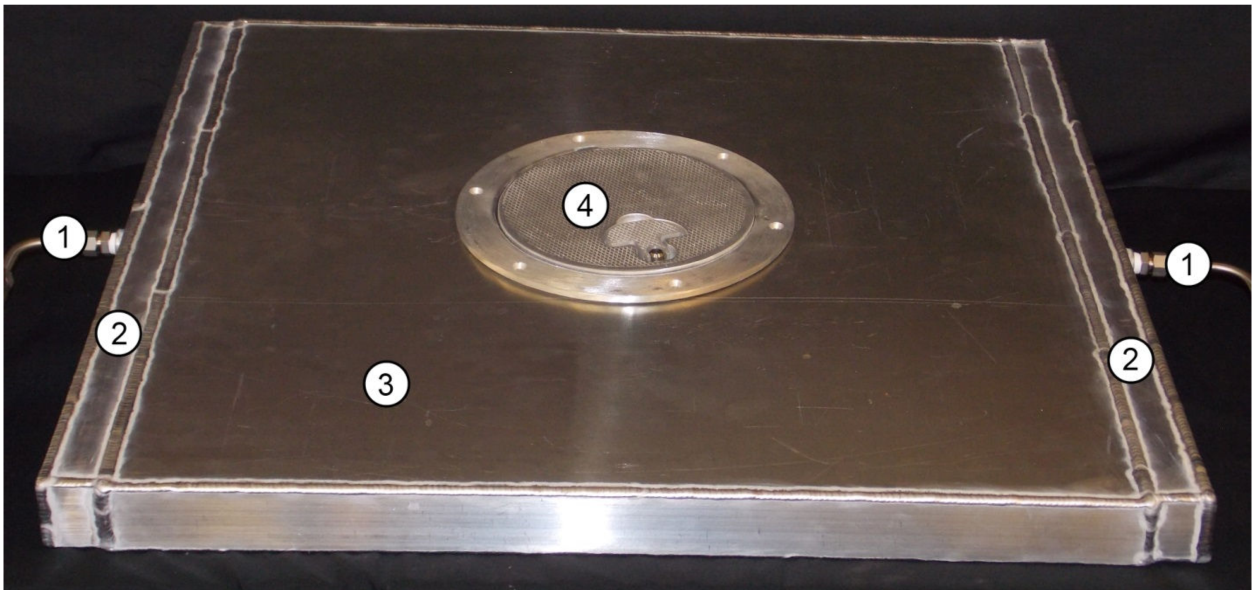
A steady state ECU model was developed to evaluate the effect of thermal storage on power consumption of this system. Modeling indicated that the PHX needed to reject 2.1 MJ over two hours to provide a 6-7% reduction in power consumption. The PHX was demonstrated at ACT's laboratory using a low fidelity prototype. The PHX prototype was sized to fit under a standard 18k ECU. Integrating the PHX in this manner would result in a 10% increase in the height of the ECU. Initial calculations indicated that the PHX must absorb 2.2 MJ of energy over 2 hours to meet DOD requirements. This required approximately 25 lbs. of PCM.

Testing of the PHX over a range of flow rates indicated that the Phase I prototype, which was not optimized, was capable of accepting an average energy transfer rate of 280 W with a coolant flow rate of 0.24 gpm (0.91 Lpm). This low flow rate, combined with a nearly negligible pressure drop of 0.1 psi (690 Pa), indicates that the pump required for the PHX would draw minimal power, less than a Watt, which is negligible compared with the power consumption of an ECU.

The target energy transfer rate was 300 W to meet the 2.1 MJ requirement. The Phase I prototype fell short by 7%. However, surface temperature measurements and CFD results indicate that the basic approach used for the PCM flow volume resulted in uneven flow

distribution and inefficient use of PCM. In Phase II, ACT will conduct a design study to optimize this feature and improve the energy transfer rate of the PHX.

The primary goal of the Phase II is to advance the state-of-the-art related to the PHX/ECU system. This work will involve a wider range of testing and modeling to optimize flow distribution within the PHX, finalize the ECU integration strategy, and develop a control strategy to enhance power consumption gains. We will work with our military and commercial partners to provide a smooth transition to product development after Phase II.



1 - Liquid Port (3/8 in. NPT)
2 - Distribution Plenum (1-5/8 in. x 28-1/2 in. x 2 in.)
3 - PCM Containment Volume (27 in. x 28-1/2 in. x 2 in.)
4 - PCM Fill Port (10-1/2 in. diameter)